hydrogen facts

PRODUCTION OVERVIEW

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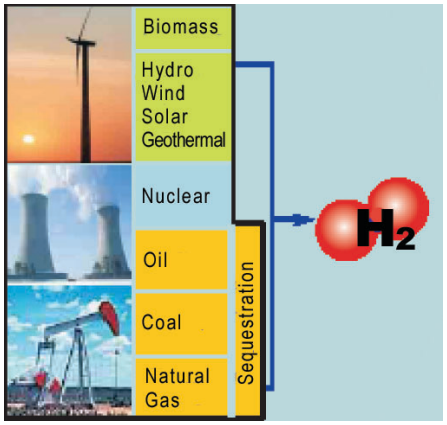
The future hydrogen economy will feature hydrogen as an energy carrier in a reliable and sustainable energy supply system. In today's energy supply system, electricity serves as an energy carrier. Electricity made by the conversion of primary energy sources (see text box) is easily transported and delivered to end-users. Building an infrastructure that allows for easy and cost-effective transportation and delivery of hydrogen energy is a critical step toward a future hydrogen economy.

Sources of Hydrogen

Hydrogen does not exist alone in nature. We must extract it from a hydrogen-containing substance or feedstock. Water (H_20), an abundant natural resource, contains hydrogen as does natural gas (which contains about 95% methane-CH_4), biomass (cellulose) and hydrocarbons like coal and natural gas. Hydrogen can be produced from diverse, naturally occurring feedstocks using an equally diverse array of primary energy sources. It's this diversity of options that enables hydrogen production almost anywhere in the world.

Figure 1: Sources of hydrogen



Source: U.S. Department of Energy

PRIMARY ENERGY SOURCES
Primary energy sources are found or stored in nature. They include biomass, coal, oil, natural gas, sunlight, wind, water, nuclear power from radioactive substances, geothermal power and potential energy from the Earth's gravity.

SECONDARY ENERGY SOURCES & FEEDSTOCKS
Secondary sources of energy are produced from primary energy sources using technology. These secondary energy sources, or *energy carriers*, include the electricity produced from coal or photovoltaics, and ethanol produced from corn. In the latter example, the resource (corn) from which the energy carrier (ethanol) is extracted, is called a feedstock. Hydrogen is an energy carrier that can be produced from a wide variety of feedstocks.

Hydrogen Production

All hydrogen production processes are based on the separation of hydrogen from hydrogen-containing feedstocks. The feedstock dictates the selection of the separation method. Today, we use two primary methods to separate hydrogen: thermal and chemical. A third method, biological, is in the research and development phase.

Today, 95% of the hydrogen produced in the U.S., roughly 9 million tons, uses a thermal process with natural gas as the feedstock. This process, called steam methane reformation (SMR), consists of two steps: 1) reformation of the feedstock with high temperature steam supplied by burning natural gas to obtain a synthesis gas, and 2) using a water-gas shift reaction to form hydrogen and carbon dioxide from the carbon monoxide produced in the first step.

STEAM METHANE REFORMATION

Step 1: $CH_4 + H_2O \Rightarrow CO + 3\,H_2$

Step 2: $CO + H_2O \Rightarrow CO_2 + H_2$

To a lesser degree, the U.S. also produces hydrogen electro-chemically from water when higher purity hydrogen is needed (See Fig. 2). The process, called electrolysis, passes electricity through water in an ionic transfer device to separate water into its hydrogen and oxygen parts. Many link renewable primary energy sources and electrolysis to produce hydrogen since this combination produces no pollution. In France, an abundance of nuclear power makes electrolysis a logical, and their most common, method for producing hydrogen.

ELECTROLYSIS

electricity + $2H_2O \Rightarrow O_2 + 2H_2$

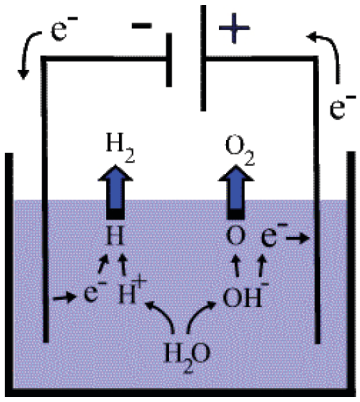


Figure 2. Electrolysis: using electricity to split water

All production technologies have a variety of costs and benefits with regard to the environment, economics, security and other concerns.*

Production Infrastructure

The development of a national hydrogen production infrastructure to support a hydrogen economy could evolve along one or more pathways using, for example, a distributed production infrastructure located at the point of use, or a centralized production infrastructure at large industrial production sites. While distributed hydrogen production requires smaller capital investments and a minimal transport and delivery infrastructure, centralized production achieves the economic benefits of mass production. Power Parks, which typically produce hydrogen during off-peak hours to provide electricity during high grid loads or blackouts, offer another production pathway for providing transportation fuel.

DISTRIBUTED PRODUCTION – Located at the point of use; scalable. Often produces small quantities of hydrogen (To refuel about 1-50 vehicles per day).

CENTRALIZED PRODUCTION – Central production station featuring pipelines or other transport infrastructures to deliver the hydrogen to points of use. (To refuel about 50,000 vehicles per day.)

Role in the Transition to a Hydrogen Economy

A new hydrogen economy requires cost-effective hydrogen production and expanded hydrogen infrastructure to ensure that end-users have convenient access to hydrogen energy. Like many technologies, research, development and demonstration must continue to lower cost, increase efficiency and address emissions issues associated with some hydrogen production technologies. The transition to a hydrogen economy features a variety of processes from a diverse resource base. At this point, the U.S. transition will likely build on the existing infrastructure and begin with a fossil fuel-dominant mix in the near-term, followed by an increasing presence of renewables and possibly nuclear energy in the long-term.

Major Hydrogen Production Processes

Primary Method	Process	Feedstock	Energy	Other
Thermal	Steam Reformation	Natural Gas	High temperature steam	Some emissions. Carbon sequestration can mitigate their effect.
	Thermochemical Water Splitting	Water	High temperature heat from advanced gas-cooled nuclear reactors.	No emissions.
	Gasification	Coal, Biomass	Steam and oxygen at high temperature and pressure.	Some emissions. Carbon sequestration can mitigate their effect.
	Pyrolysis	Biomass	Moderately high temperature steam.	Some emissions. Carbon sequestration can mitigate their effect.
Electrochemical	Electrolysis	Water	Electricity, including wind, solar, nuclear and coal.	No emissions during electrolysis process.
	Photoelectrochemical	Water	Direct sunlight.	No emissions.
Biological	Photobiological	Water and algae strains	Direct sunlight.	No emissions.
	Anaerobic Digestion	Biomass	High temperature steam.	
	Fermentative Micro-Organisms	Biomass	High temperature steam.	

** For more information on hydrogen and to view the electronic version of this fact sheet, please visit www.HydrogenAssociation.org or www.eere.energy.gov/hydrogenandfuelcells/*

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